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ABSTRACT

This qualitative study investigates the nature of the cognitive processes learners use in HyperCard environments: whether students' cognitive processes differ in learner-controlled versus program-controlled environments, and how much students learn in each. Participants were 20 undergraduate students in the college of education at a large southwestern university who were novices at using HyperCard. No overall dramatic differences between the learner- and program-controlled groups were found for cognitive processes in hypertext learning environments. The type of environment did not appear to correlate with appreciable differences in learners' cognitive processes. Ability differences, however, were found to be significant. The results of this study support previous findings that learner-controlled versions of hypertextual materials may be inappropriate for low ability students. Qualitative participant differences (i.e. interests, preferences) were also found to be meaningful, regardless of learning environment differences. (Contains 34 references.) (Author/AEF)

Learner Control, Cognitive Processes, and Hypertext Learning Environments

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Abstract

This qualitative study investigates the nature of the cognitive processes learners use in *HyperCard* environments: whether students' cognitive processes differ in learner-controlled versus program-controlled environments, and how much students learn in each. No overall dramatic differences between the learner- and program-controlled groups were found for cognitive processes in hypertext learning environments. The type of environment, learner- or program-controlled, did not appear to correlate with appreciable differences in learners' cognitive processes. Ability differences, however, were found to be significant. The results of this study supported previous findings that learner-controlled versions may be too difficult for low ability students. Qualitative participant differences (i.e., interests, preferences) were also found to be meaningful, regardless of learning environment differences.

Introduction

Previous research has shown that the type of computer-mediated environment, learner- or program-controlled, is not as significant as the learner's general academic ability in determining the success or failure of computer-assisted instruction (CAI) in general, and hypertext in particular. Cognitive processing in relation to learner control issues in hypertext learning environments, however, has not been examined. Therefore, my dissertation study investigated the nature of the cognitive processes learners use in *HyperCard* environments: whether students' cognitive processes differed in learner-controlled versus program-controlled environments, and how much students learned in each.

Method

Participants in this study were twenty undergraduate students in the College of Education at a large southwestern university. They were novices in using *HyperCard* and had limited knowledge of the buildings located on Congress Avenue, a main street in the city in which the university was located. Students were equally divided into two groups and asked to think aloud while learning information about historic buildings on Congress Avenue, using either learner- or program-controlled *HyperCard* programs. Participants were audio- and video-taped during the learning task. After finishing *HyperCard* learning, participants completed a recall of information posttest, were asked about what they had been thinking while watching video segments of their learning task, and were encouraged to answer questions regarding their opinions about the program.

Data Analysis

The collected data included: (1) responses on the self-report questionnaire regarding descriptive information about participants such as SAT scores and their experiences with the *HyperCard* program and content knowledge; (2) audio and videotapes presenting participants' learning behavioı during the *HyperCard* learning; (3) recorded verbal data acquired from participants' think-aloud, stimulated-recall, and interview data; (4) learning paths and time on task identified from the *HyperCard* program; and (5) learning outcomes estimated from the results of posttests. Think-aloud and stimulated-recall protocols were analyzed with protocol analysis procedures (Ericsson & Simon, 1984) and interview data were analyzed using emergent theme analysis (Lincoln & Guba, 1985). Foı identifying group differences, statements on each type of cognitive process activity, time on task, and learning outcomes, were tested by a t-test, and rank-ordered and tested by the Mann-Whitney U Test (Siegel, 1956).* These statistics were used to examine the probability that observed differences would have occurred by chance. Low probabilities of chance occurrence (less than .20 chance) were used as support for group differences. For triangulation of statistical analysis results, t (by t-test), U and z scores (by the Mann-Whitney U Test) were reported simultaneously. The statistical analysis in this study was used as supporting evidence for the results of the qualitative analysis.

Results and Discussion

The analyses of cognitive processes in hypertext learning environments identified no overall substantial differences between the learner-controlled (LC) and program-controlled (PC) groups. In both groups, the verbalizations of metacognitive processes were most frequently stated within each type of cognitive process activity. The LC group produced 40% of all statements on metacognitive processes, 27% on reading processes, 18% on computer operation, 14% on parallel cognition, and 1% undecided, whereas the PC group showed 38%, 23%, 24%, 14%, and 1%, respectively.

Despite the absence of dramatic differences, certain subtle differences between the LC and PC groups were identified in statements about metacognitive processes, reading processes, and computer operation. Metacognitive processes in this study pertain to understanding processes themselves (e.g., "OK," "I understand it," "Wait," or "I like it"). LC group members were more involved in metacognitive processes in general ($t(12) = 1.84$, $p = .09$; $U = 11.0$, $z = -1.73$, $p = .08$), and control processes in particular, than PC group members ($t(12) = 2.08$, $p = .06$; $U = 7.0$, $z = -2.24$, $p = .03$). This suggests that LC group members were more active in higher-level metacognitive processes than PC group members as reflected in their evaluations of materials and decision-making processes. Reading processes in this study pertain to reading a text for understanding or comprehension of content (e.g., "opened a general store," or "Why does he have to build the things bigger than that?"). LC group members also made both more reading verbatim ($t(12) = 1.33$, $p = .21$; $U = 13.0$, $z = -1.47$, $p = .14$) and comprehension statements than PC group members ($t(12) = 1.31$, $p = .22$; $U = 12.5$, $z = -1.54$, $p = .12$). This suggests that LC group members dealt more actively with materials by reading and by comprehending information during *HyperCard* learning than PC group members. Computer operation statements, in this study, are comments made which generally concern how to do something with the Macintosh computer and/or the *HyperCard* program (e.g., "Click on (something)," or "Where do I go?"). No group difference was found in computer operation, indicating that participants in both groups devoted equivalent amounts of time to operating the program throughout the lesson. It is, therefore, possible that participants in both groups did not become more skillful in the use of the program as they progressed. Also, less time may have been devoted to metacognitive and reading processes during *HyperCard* learning due to participants' focus upon computer operation.

The learner-controlled nature of hypertext creates a number of possibilities in reading information and allows readers to decide what information to read and in what order (Charney, 1987; Conklin, 1987; Gay & Mazur, 1991). The learner-controlled version of the stack used in this study might have interfered with users' reading processes because participants may have had to attend more to operation of the program than the program's content (Conklin, 1987; Tomek, Khan, Mldner, Nassar, Novak, & Proszynski, 1991; Tsai, 1989). In contrast, the program-controlled version was structured in a way so that learners would not have to decide how to use the program. It was, therefore, expected that PC group members could have been more involved in reading the materials. However, in this study, LC group members turned out to be more involved in reading materials in hypertext learning than PC group members, whereas participants in both groups devoted as much time to operating the program. This indicates that the PC version did not help students operate the program as presumed and participants in both groups, despite the group to which they belonged, were confused during *HyperCard* learning.

Participants in this study were novices in *HyperCard* (the system) use and Congress Avenue (the content). Only a few students were familiar with one or two of the buildings on Congress Avenue before learning the lesson. Participants' lack of experience in *HyperCard* use and limited knowledge of the content may have caused them to be confused (or disoriented) about the operation of the program throughout the lesson (Conklin, 1987; Gay & Mazur, 1991; Halasz, 1988; Tomek, et al. 1991). Also, these novices were asked not only to read the new and specific information, but also to operate the program and memorize the texts on the screen for the impending test. These dual tasks of learning and navigating the program with lack of prior knowledge of the content and the system caused some participants, low ability students in particular, to become cognitively overloaded during *HyperCard* learning. This was explicitly expressed in think-aloud protocols (e.g., "getting dull," "there are so many here," "seems too long," or "I'm tired") and stimulated-recall and interview data results regarding the feeling of cognitive overload. For example, a low ability student expressed his feeling of cognitive overload:

I think by this time I felt I was getting almost overloaded with the information, because I've been going down the street now on probably the building eleven or ten or so and it was like all the history of each building, all the architecture of each building, and all that real locations. Probably everybody else could've handled it, but I thought it was quite a lot of information after a while. This supports previous research findings that using hypertext may be a problem for low ability students due to cognitive overload (Park, 1992; Tsai, 1989).

Although LC group members showed more active metacognitive processes and more actively dealt with materials in the program than PC group members, they did not perform any better on the test (14.9 out of 25) than PC group members (17.6). One possible reason is that LC group members, when compared to PC group members, did not seem to see all the available materials in the stack. This was supported by the time on task data results which revealed that LC group members took less time on task (19.1 minutes) than PC group members (27.7 minutes). However, PC group members, no matter how much they may have been confused about the program, had to go through all the materials, perhaps resulting in better performance on the test than LC group members. This suggests that program-controlled versions of hypertextual materials may help students remain longer in the program, thus assisting them to better recall information.

Another possible reason for group differences in recall is that the condition difference in this study was not extreme enough to make any distinction between the LC and PC groups in learners' cognitive processes. There are several learner control variables such as pace, sequence, and content (Gay, 1986; Milheim & Martin, 1991). The only condition difference provided in both versions of the program in this study was the sequence control levels (Gray, 1987). Participants in this study were heavily involved in operating the program throughout the lesson, as qualitative and quantitative results revealed, rather than being engaged in in-depth reading during *HyperCard* learning. These results were not expected, given previous research findings which stated that PC group members, given the PC structure, were less involved in computer operation than LC group members in hypertext learning environments (Tsai, 1989). However, the PC version in this study, when compared to the LC version, apparently did not make program operation easy enough to enable learners to concentrate only on reading the materials in the program. Thus, participants in both groups equally and steadily involved themselves in the operation of the program throughout the lesson.

There were ability differences displayed in learning outcomes in this study, but not condition differences. Participants in this study, instead of displaying differences in cognitive processes between the LC and PC groups, showed strong ability-related differences in learning outcomes. High ability students (those who got over 1100 in SAT in this study) took more time for *HyperCard* learning ($t(12) = -1.75$, $p = .11$), vocalized fewer computer operation statements ($t(12) = 1.85$, $p = .09$; $U = 10.5$, $z = -1.74$, $p = .08$), and performed better on the test ($t(12) = -1.59$, $p = .14$; $U = 12$, $z = -1.57$, $p = .12$) than low ability students (those who got less than 1100 in SAT). This suggests that high ability students had no difficulty in learning the content of the program. However, low ability students in the LC group had the lowest recall scores on the test, indicating that these students may not have been able to effectively use the LC version. This ability difference was more evident when combined with time on task and computer operation data. Low ability students in the LC group took similar amounts of time on task, yet recalled the information more poorly than those in the PC group ($t(6) = -1.59$, $p = .16$; $U = 3.5$, $z = -1.31$, $p = .19$). In addition, low ability students in the LC group had as many computer operation verbalizations as those in the PC group, yet performed more poorly than those in the PC group. This ability difference in combination with time on task and computer operation revealed that the LC version may have been ineffective for low ability students to use.

The findings associated with ability difference in this study confirmed previous research on CAI in general (Garhart & Hannafin, 1986; Gay, 1986; Gillingham, Garner, Guthrie, & Sawyer, 1989; Goetzfried & Hannafin, 1984; Hannafin, 1984; Lee & Lee, 1991; Steinberg, 1977, 1989) and hypertext in particular (Balajthy, 1990; Charney, 1987; Gay, Trumbull, & Mazur, 1991; Lanza & Roselli, 1991; Lee & Lee, 1991; Lee & Lehman, 1993; McGrath, 1992; Tsai, 1989). Researchers have postulated that less able students are not well suited for learner-controlled versions of hypertext learning environments. The freedom of navigation inherent in hypertext may be difficult to use, particularly for low ability students. However, the findings in this study indicated that low ability students in the PC group, although they devoted as much time to operating the program as those in the LC group, could do better on the test than those in the LC group. The PC version, therefore, may have been better for low ability students, whereas the LC structure may have been difficult for low ability students to use. This suggests that some PC versions might be effective for participants, low ability students in particular, in hypertext learning environments. For example, program-controlled instructional cues to view embedded information may be helpful to low ability students in hypertext environments (Lee & Lehman, 1993).

The findings of this study provide some suggestions for instructional design. Theoretically, hypertext is completely controlled by the user (Park, 1992). However, because learners who have choices may not fully use all aspects of each program, enhanced versions of hypertext combining both the learner-controlled and program-controlled structures can be used for instructional purposes. Although this particular *HyperCard* stack, as students pointed out during their interviews, may not be good for in-depth presentations, *HyperCard* and other easy authoring languages are expected to be useful for developing educational materials. A combination of LC and PC versions of hypertext learning environments may be able to reach out to more diverse target audiences. For example, high ability students could use learner-controlled versions, whereas low ability students should use enhanced versions of hypertext, combining both LC and PC structures

Another design consideration of hypertext learning environments is that navigational tools (or orientation aids) are required to help students (Gray & Shasha, 1989). Because students in this study were novices in *HyperCard* use and Congress Avenue, they sometimes tended to be disoriented and cognitively overloaded. This lack of experience caused them to be confused about the operation of the program throughout the lesson. This was confirmed by think-aloud data results that showed that participants in both groups did not become more skillful in program operation as they progressed through *HyperCard* learning. The map in the *HyperCard* stack, used as a navigational tool in this study, did not help those who lacked prior knowledge of Congress Avenue. More diverse navigational tools, therefore, should be incorporated, particularly as the content level becomes increasingly complex in hypertext learning environments. Various types of navigational tools such as guided tours, visual maps, fisheye views, browsers, and learning guides were suggested for use in previous studies (Conklin, 1987; Gay & Mazur, 1991; Gay, et al., 1991; Gray & Shasha, 1989; Halasz, 1988; McGrath, 1992; Park, 1992; Reynolds, Patterson, Skaggs, & Dansereau, 1991; Tsai, 1989; Tomek, et al., 1991).

The findings of this study also call for future work on cognitive processes unique to hypertextual environments (Marchionini, 1989; Kozma, 1991). In this study, each type of cognitive process activity, including metacognitive processes, reading processes, computer operation, and parallel cognition were classified based upon previous research done on reading and computer searching (Shell, Horn, Svoboda, & Dongilli, 1990; Shell, 1990). While revising scoring categories previously established for think-aloud data, I found it difficult to locate scoring categories that were unique to hypertext learning environments. Those categories were not related to existing reading or computer search categories, such as "my name is (something)" and "it says hello to you." Unique scoring categories should be developed for use in later research on cognitive learning in hypertext learning environments. As a result, perhaps a more detailed picture of the cognitive processes that learners employ in hypertext learning environments will be drawn.

In addition, there is a possibility that the subject matter domain in the program (historic buildings) was presented at an introductory level too basic for the study participants, which may have resulted in similarities between the LC and PC groups in verbalized cognitive processes. Perhaps recall of the information was limited because the content was basically verbal information. However, hypertext may be suitable for "ill-structured domains" which require more advanced-level learning. With the help of hypertext, learners can explore the same phenomenon from multiple perspectives, which may lead to better comprehension (Spiro & Jehng, 1990). Presumably, this particular lesson did not provide the best means for examining learners' cognitive processes in hypertext learning environments (Alexander, Kulikowich, & Jetton, 1994; McGrath, 1992). Hypertext programs with subject matter which includes problem-solving (e.g., literature, psychology, social studies, science, mathematics, or computer science) could be more suitable for investigating future process-focused research on hypertext environments (Alexander, et al., 1994). Conclusion

I found that in this study, learners' cognitive processes did not differ much between the LC and PC groups. In other words, condition differences did not appear to create any appreciable differences in learners' cognitive processes in hypertext learning environments. However, ability differences, the secondary focus in the study, were found to be significant. In particular, this study supported previous findings that learner-controlled versions of hypertextual materials may be inappropriate for low ability students. Qualitative individual differences (i.e., interest, preferences) emerged and were also meaningful, regardless of condition differences. Individual learning styles and preferences along with ability levels, therefore, are presumed to affect the moment-to-moment selection of options in hypertext learning environments.

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